Stakeholder Conflict Resolution Model (S-CRM) Based On Supervised Learning

Chang-Kyun Jeon[1], Neung-Hoe Kim[1], Dong-Hyun Lee[1], Taek Lee[1] and Hoh Peter In[1]
[1]Department of Computer Science & Engineering, Korea University
Anam-Dong, Sungbuk-Gu, Seoul 136-713, Korea
[e-mail: curt_jeon, nunghoi, tellmehenry, comtaek, hoh_in@korea.ac.kr]
*Corresponding author: Hoh Peter In

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Abstract

Various stakeholders are involved in the creation of software projects. In general, the higher the number of stakeholders involved during the requirements elicitation phase, the better are the chances of success for the project. However, it is rather difficult to consider the opinion of all the stakeholders owing to constraints on time and resources. Furthermore, conflicts between stakeholders can become inevitable when the number of stakeholders increases. Thus, the identification of key stakeholders is an important factor in ensuring the success of a project.

In this paper, a methodical stakeholder conflict resolution model (s-CRM) is proposed by considering an actual industrial case study. The proposed model uses information gain based on entropy when measuring the impurity of information. We believe that the proposed s-CRM is effective in identifying the key stakeholders and in intuitively indicating those stakeholders whose elicited requirements need to be weighted. In addition, the model provides a solution for conflicts among stakeholders during requirements engineering.

Keywords: Stakeholder, conflicts, requirements engineering, entropy, information gain

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1. Introduction

Effective requirements elicitation is a key success factor in software development. If one of the stakeholders of a particular software is not satisfied owing to poor requirements elicitation, the software will be eventually scrapped [1][2][3]. However, it is difficult to elicit requirements from multiple organizations or a high number of stakeholders with different roles, interests, and responsibilities. If the number of stakeholders increases, more conflicts occur among stakeholders and reaching an agreement becomes a challenge [4][5]. How to effectively resolve requirements conflicts among multiple stakeholders who have different roles, interests, and responsibilities?

In this paper, we propose a stakeholder conflict resolution model (s-CRM) for resolving requirement conflicts on the basis of the supervised learning method. A supervised learning method is used to measure the impurity of information and classify useful information from trusted stakeholders who have a high impact on requirement negotiation. The conflicts are resolved by prioritizing stakeholders using entropy, a measurement of supervised learning. In other words, the stakeholders having low entropy (trusted stakeholders) are respected in requirements elicitation more than those having high entropy. However, current studies on determining the key stakeholders and resolving conflicts using traditional methods have dealt with the relationship and organization of each stakeholder. In addition, they do not propose a systematic framework for resolving conflicts.

To develop a method for first identifying the key stakeholders and determining the intuitive criteria for solving conflicts regarding the requirements, we need to quantify the degree of importance of the stakeholders. A supervised learning method is used to classify the requirements and to measure the entropy and information gain in order to determine the priority of the stakeholders. In Section 2, the related works are reviewed, and in Section 3, we describe the use of s-CRM to resolve conflicts between stakeholders. Section 4 presents a case study on a mobile terminal product based on platform-based software development. Finally, Section 5 presents some concluding remarks regarding our study and discusses future work.

2. Related Works

2.1 Stakeholder Analysis

Research on stakeholder prioritization has been carried out for a long time. However, many researchers have struggled to prioritize stakeholders on the basis of the relationship between an organization and its management scenario. They have considered the relationships between stakeholder goals and positions and have described a method for defining their dependencies. Rawlins stated that a stakeholder analysis can be carried out by identifying and defining the stakeholders according to their attributes, interactions, and interests in terms of their relationship with the issue at hand. Donaldson and Preston argued that the stakeholder theory explicitly or implicitly includes three different types of theories: descriptive/empirical, instrumental, and normative [6]. Hill and Jones, and Cornell and Shapiro referred to stakeholders as contractors or participants in exchange relationships [7]. Cameron et al. presented a process for ranking stakeholders on the basis of their needs and their relative importance in each other's network [8]. Fletcher et al. presented a process for mapping stakeholder expectations, which uses value hierarchies and key performance areas (KPAs) [9]. Turner, Kristoffer, and Thurloway developed a method for identification,

awareness assessment, support, and influence to develop communication strategies and assess stakeholder satisfaction, and to determine which stakeholders are aware of strategies and whether they have a supportive or opposing attitude [10]. In a typical stakeholder analysis, the types of stakeholders are as follows:

- *Primary stakeholders* are those ultimately affected, either positively or negatively, by an organization's actions. Businesses consider primary stakeholders as those with an investment in a particular business matter. The stakeholders are interested in the organization's overall strategies and success, as they stand to gain or lose through such actions.
- *Secondary stakeholders* are the intermediaries, that is, persons or organizations, who are indirectly affected by an organization's actions, as well as those who are not directly impacted by an investment but experience some sort of change regardless.
- *Key stakeholders* (who can also belong to either of the first two groups) have a significant influence on, or importance within, an organization.

Stakeholder analysis is an approach frequently used to identify and investigate the barrier formed by any group or individual who can affect or is affected by the achievement of the objectives of an organization. Stakeholder analyses have attracted considerable attention and are now integral to any participatory natural resource management initiatives. Another approach to categorizing stakeholders has been proposed by Carl and John. They designed a framework that groups stakeholders into four categories: principals, end users, partners, and insiders [11].

Some researchers have simply discussed the important role stakeholders play in enhancing the organizational wealth and economic benefits, and they have tried to identify a process to gauge stakeholder requirements. However, such an approach does not provide a normalized process or method for prioritizing the different stakeholders and solving the conflicts among them. In other words, the approaches described above classify stakeholders on the basis of their relationships and map their positions in terms of their economic benefits.

2.2 Supervised Learning: Impurity function, Entropy, and Information gain

Supervised learning is a machine-learning task for inferring a function from supervised training data. An algorithm analyzes the training data and generates an inferred function to be used as a classifier. For clearing a key stakeholder, an impurity function is selected to measure the selection of attributes of the key stakeholder. Originally, the impurity function measures the extent of purity for a region containing data points from possibly different classes. Information gain measurement is based on the entropy function derived on the basis of information theory [12][13].

$$entropy(D) = -\sum_{j=1}^{|C|} \Pr(c_j) \log_2 \Pr(c_j), \quad \sum_{j=1}^{|C|} \Pr(c_j) = 1$$

where $Pr(c_j)$ is the probability of class c_j in dataset D and is the number of examples of class c_j in D divided by the total number of examples in D.

To determine which attribute reduces the impurity the most, the number of possible values of the attributes A_i to be v should be considered. When using A_i for partitioning dataset D, we divide D into v disjoint subsets, D_1, D_2, …., D_v.

The entropy after the partition is calculated as follows:

$$entropy_{A_i}(D) = \sum_{j=1}^{v} \frac{|D_j|}{|D|} \times entropy(D_j)$$

The information gain of attribute A_i is

$$gain(D, A_i) = entropy(D) - entropy_{A_i}(D)$$

Clearly, the attribute with the lowest entropy value is selected to identify the key stakeholders.

3. Stakeholder Conflict Resolution Model (s-CRM)

s-CRM consists of two steps. Each step is divided into several phases, as shown in **Fig. 1**. Each phase takes the results from the previous phase or data. Some outputs from the previous phase are used as inputs for the next phase. In addition, the steps have different attributes as input data.

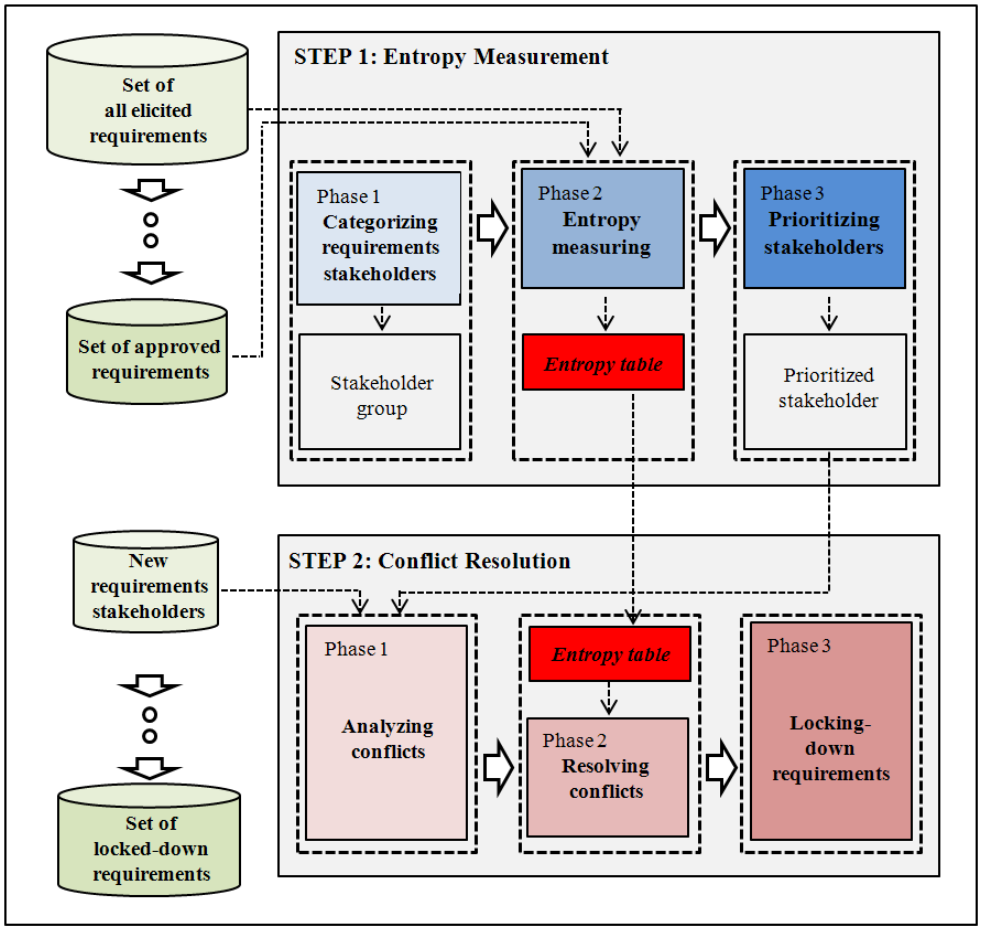


Fig. 1. Stakeholder Conflict Resolution Model (s-CRM) framework

Step 1 is carried out to measure the entropy between requirements and stakeholders. It takes elicited and approved requirements as input for categorization, entropy measurement, and stakeholder prioritization; after entropy measurement, it yields an entropy table for conflict resolution in the step 2. For effective entropy measurement, we must be able to categorize stakeholder representatives appropriately, determine the reasons for their requirements, identify related requirements, understand which requirements is interacting and combining with each other, and predict the outcome if a requirement is rejected. The accuracy of the calculated value increases with the number of products and requirements applied for entropy calculation.

On the other hand, Step 2 takes newly elicited requirements and a set of stakeholders as inputs, which are combined with the previous entropy. This step involves conflict analysis to identify conflicting requirements and stakeholders, conflict resolution using the entropy calculated in Step 1, and requirement lockdown.

Finally, it outputs a set of requirements on the basis of the suggested prioritized stakeholders. Each proposed step can be carried out as follows.

3.1 Step 1: Entropy Measurement

The entropy measurement step is used for calculating the entropy of each stakeholder with respect to the approved requirements. By combining early elicited and finally approved requirements and stakeholders, an entropy table can be created to resolve stakeholder conflicts.

Phase 1: Categorizing Requirements-Stakeholders

In the first phase of Step 1, the representatives of stakeholders are identified and categorized to determine their interests and requirements. In this phase, a categorized table is created based on the stakeholder and requirements status.

Table 1. Categorizing requirements and stakeholders

	Government Regulator	Developer	Product Planner	Stakeholder$_4$	Stakeholder$_5$	....	Stakeholder$_n$	Approved Status
	Stakeholders							
Radio Resource Management Specification	×	×	×	✓			×	●
Custom Media Format for Streaming Service		×	×	✓			✓	●
CR$_3$		×	✓	×	✓			
CR$_4$	✓			✓			✓	●
CR$_5$			✓	✓			✓	●
⋮								
CR$_n$		×	✓		✓		✓	

Elicited Requirements

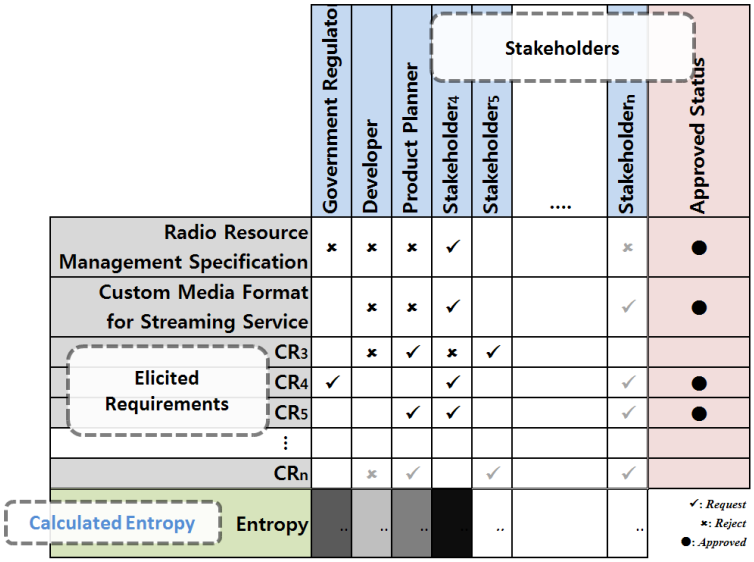
✓: *Request* ×: *Reject* ●: *Approved*

Phase 2: Entropy Measuring

During this phase, using the proposed entropy and information formula, each stakeholder has a different entropy gain. This is a basis for prioritizing the stakeholders. Note that highly

influential stakeholders can be distinguished from others on the basis of the calculated entropy gain.

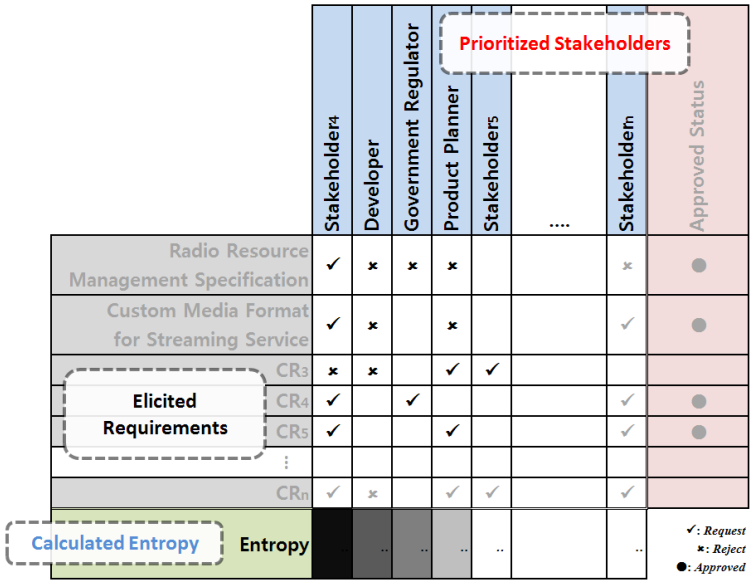
Table 2. Entropy measuring



Phase 3: Prioritizing Stakeholders

In this phase, stakeholders are prioritized for conflict resolution in the next step as shown in **Table 3**. The entropy calculated in the previous phase is used to prioritize the stakeholders. The stakeholders are arranged from left to right in decreasing order of priority.

Table 3. Prioritizing stakeholders with entropy



3.2 Step 2: Conflict Resolution

This step is used for checking which new stakeholders or requirements have a conflict with the approved requirements and for making a correct decision in accepting the requirements or determining the key stakeholders in an upcoming product based on the calculated entropy. In this step, the opinions of domain experts familiar with the details of the domain area are needed. It is important to determine the interests of each stakeholder and the reasons for their requirements because it is necessary to consider important factors or relationships with respect to the business goal.

Phase 1: Analyzing Conflicts

This phase redefines the conflicts between the requirements based on the newly elicited requirements and listed stakeholders shown in **Table 4**.

Table 4. Adding new requirements and stakeholders

	Stakeholder$_1$	Developer	Government Regulator	Product Planner	Stakeholder$_5$	....	Stakeholder$_n$	Carrier	New Stakeholder$_2$	....	New Stakeholder$_m$	Approved Status
							New Stakeholders					
Radio Resource Management Specification	✓	×	×	×			×	✓			×	●
Custom Media Format for Streaming Service	✓	×		×			✓		✓			●
CR$_3$	×	×		✓	✓			✓	×		✓	
CR$_4$	✓		✓				✓		×			
CR$_5$	✓			✓			✓	×	✓			●
⋮												
CR$_n$	✓	×		✓	✓		✓					
Customized User Inferface		✓	×					✓	✓		✓	
New CR$_2$	✓			✓	×			×	✓		×	
⋮												
New CR$_m$	✓		✓		×			✓	×		×	

New Elicited Requirements

✓: *Request*
×: *Reject*
●: *Approved*

Phase 2: Resolving Conflicts

By comparing the prioritized stakeholders based on the entropy and newly listed stakeholders, we can intuitively understand which stakeholders have changed their position and which are new as shown in **Table 5**. In this stage, it is important to determine why new stakeholders are added to the list from the point of view of the business goal. To solve these conflicts, the proposed rule sets are declared.

- *The confirmed requirements have been approved by the key stakeholders, and the primary stakeholders are not included in the conflict resolution phase.* Even if a new stakeholder requests to reject an approved requirement, with the exception of a revision in the architecture, we do not need to consider an acceptable substitution.
- *The requirements requested by the new stakeholder are in conflict with the approved requirements.* With considering the corresponding stakeholder's entropy in that domain, the entropy value is below that criteria, it is possible to be disregarded

Table 5. Analyzing and resolving conflicts with entropy

	Stakeholder$_4$	Developer	Government Regulator	Product Planner	Stakeholder$_5$	....	Stakeholder$_n$	Carrier	New Stakeholder$_2$	....	New Stakeholder$_m$	Approved Status
Radio Resource Management Specification	✓	×	×	×				✓				●
Custom Media Format for Streaming Service	✓	×		×			✓		✓			●
CR$_3$	×	×		✓	✓			✓	×		✓	
CR$_4$	✓		✓				✓		×			
CR$_5$	✓			Conflict			✓	×	✓			●
⋮												
CR$_n$	✓			✓	✓		✓					
Customized User Inferface		✓	×	Conflict				×			✓	●
New CR$_2$	✓			✓	×				✓		×	●
⋮												
New CR$_m$	✓		✓		×			✓	×		×	
Entropy		..	..	..	..		..					

✓: Request
×: Reject
●: Approved

Phase 3: Locking-down Requirements

During this phase, the candidate requirements are locked down, and the key, primary, and secondary stakeholders are identified after applying new stakeholders to the pools. A s-CRM is developed for the platform-based software development process in consumer electronics. Hence, the lockdown list needs to be reviewed and evaluated by both the key, primary stakeholder and domain experts.

4. Mobile Products: A Case Study

4.1 Background

A case study was carried out on several mobile products launched in China's third-generation of mobile terminals. These products have been developed based on new standardized specifications, and have new features provided in previous platform-based products. Thus, all serviced features and functions need to be defined from the beginning. Some of these features have to be serviced through a combination with an outside service provider such as a network provider or operator. The first set of requirements was elicited in early 2008, and commercial products were launched on the market by the end of 2009.

4.2 Experimental Results

To deal with the above difficulty, a case study was conducted on the products with the related stakeholders and domain experts. Because the requirements and specifications for these products were outlined in the preliminary stage, there were many conflicts and arguments to settle before defining the final set of requirements. We wanted to measure the impact of the key stakeholders on the decisions related to and the selection of the requirements outlined by all the stakeholders. In addition, the presented s-CRM can solve these conflicts using the calculated entropy.

The stakeholders of the initially launched platform products consist of a Carrier, Certificates, Governments Regulators, a Product Planner, Sales Marketing, a Developer, a

Service Provider, a Tester, and an Engineering Team for manufacturing. Some of these stakeholders did not give a list of requirements for the second launched product. However, some of them did request additional requirements to be applied for improving the business goals.

Table 6. Number of requirements of each stakeholder

Product	Stakeholder Groups	Number of Req.	Approved	Rejected
Based Mobile Terminal	Carrier	892	823	69
	Certificator	750	732	18
	Goverments Regulator	584	580	4
	Product Planner	1472	1211	261
	Sales Marketing	320	214	106
	Developer	394	370	24
	Service Provider	581	450	131
	Tester	450	380	70
	Engineering Team	241	213	28
	Total	5684	4973	711

**Note: All the requirements were duplicated in this study.*

Step 1: Entropy Measurement

The set of requirements for prioritizing the stakeholders of a platform product is shown in **Table 6.** Please note that we can identify the stakeholder who has influence and importance based on the entropy value shown in **Fig. 2** after carrying out Step 1. The lower entropy stakeholders are the government regulator, certification agency, carriers and developer.

After interviewing the product planner, this terminal was designed for the new standardization and specifications of a carrier in China. Hence, the government and certification gave strict rules regarding their requirements and requests. Another point to note is that the number of requirements of the developer, tester, and engineering team is relatively small compared with the other stakeholders. Because the major parts of the implemented features were already completed using another platform model, the planner simply took the features from the previous model and revised them to fulfill the requirements for this terminal.

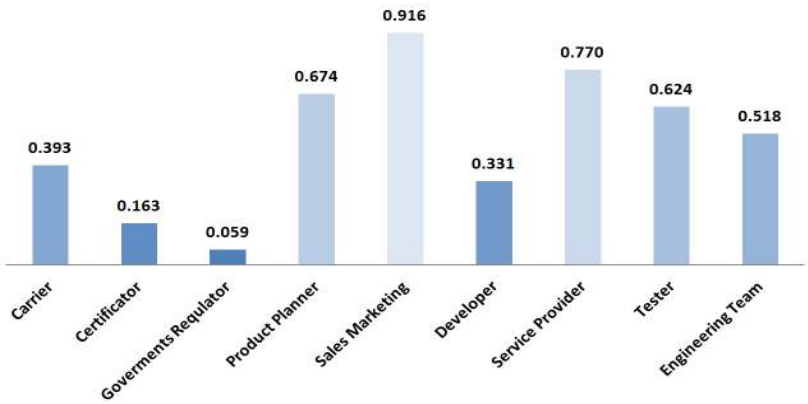


Fig. 2. Calculated entropy of each stakeholder (Step 1)

Step 2: Conflict Resolution

Clearly, there are conflicts among these stakeholders, as shown in **Table 7**. For instance, in the case of the first item**,** *radio resource management specification*, one stakeholder wants new features to be implemented to take advantage of their market position. However, some problems need to be resolved first.

The requested requirements violate the newly standardized specifications. To implement them, it is necessary to consider the impact of the developed features and the resources to be invested. By applying this case to the proposed s-CRM, we can determine the stakeholder having the lowest entropy, and the problem can be resolved by rejecting the requirement of a stakeholder with a higher entropy. Therefore, this conflict can be resolved by respecting the regulator's opinions. The practical decision is the same as that based on the result of the proposed s-CRM after interviewing related persons.

Table 7. Conflict status in case study (Step 2)

	Government Regulator	Certificator	Developer	Carrier	Engineering Team	Tester	Product Planner	Service Provider	Sales Marketing	Approved Status
Radio Resource Management Specification	×		×	✓		×				
Custom Media Format for Streaming Service			×				×	✓		
Customized User Inferface			×	✓			✓			●
⋮										
Entropy	*0.059*	*0.163*	*0.331*	*0.393*	*0.518*	*0.624*	*0.674*	*0.770*	*0.916*	

✓: Request
×: Reject
●: Approved

In the case of the second item, *custom media format for streaming service*, the requested requirements conflict with the approved requirements. By applying this case to s-CRM, the second conflicted item should be rejected owing to the entropy value of the requester. In practice, the supported media format was implemented using the platform product. To implement the requested requirements, it is necessary to discard some of the embedded features that have been serviced in the platform model. It is quite difficult to resolve these conflicts and obtain a proper and timely solution with respect to the expectations of the stakeholders. However, there is no option besides investing resources to meet all the needs of the stakeholders. Finally, this requirement is rejected after wasting a lot of resources and time.

In the case of the third item, *custom user interface*, according to the s-CRM model result, it should be rejected. However, this item was approved in practice. The related person answered that it was finally implemented to realize a better relationship with partners after considering the business goal.

We also plan to investigate the relevance of the entropy and approved rate of each stakeholder. The requirements had been elicited for the next product after development on the basis of the model. As you can see, the small number of requirements is finally approved, as shown in **Table 8**.

Table 8. The new elicited requirements for the next product

Product	Stakeholder Groups	# of New Elicited Req.	Approved	Rejected
Product Mobile Terminal	Goverments Requlator	24	22	2
	Certificator	16	16	0
	Developer	11	9	2
	Carrier	8	5	3
	Engineering Team	23	14	9
	Tester	5	3	2
	Product Planner	78	32	46
	Service Provider	3	1	2
	Sales Marketing	53	22	31
	Total	221	124	97

We carried out a comparative study on the approved rate of each stakeholder's requirements and entropy to verify the validity of s-CRM, as shown in **Fig. 3**. The higher entropy stakeholders are shown on the left side of the figure. In practice, low entropy stakeholders have higher a percentage of approved rate with respect to the suggested requirements.

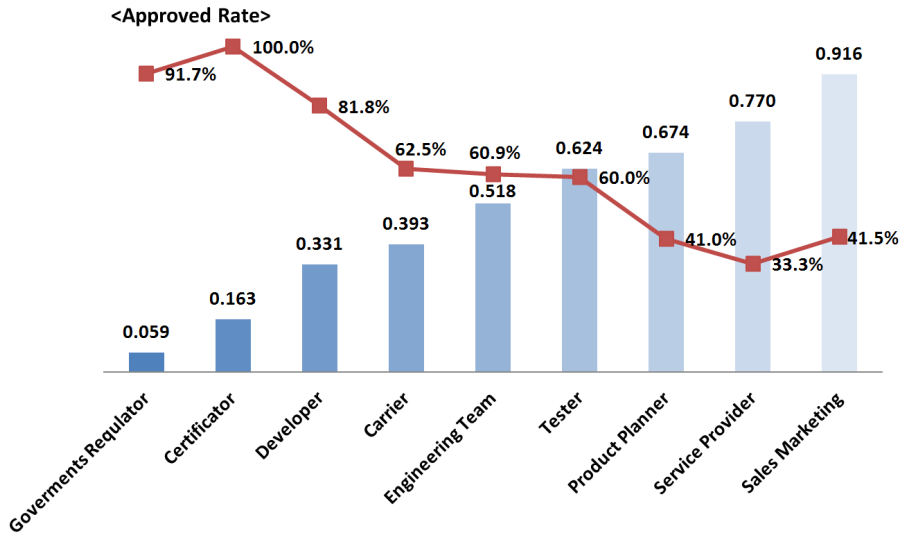


Fig. 3. Each stakeholder requirement approved rate comparing with the entropy

4.3 Implications

To determine the relevance of the results of this case study, we conducted an interview and survey with individuals who have been engaged with this platform and its related products. The survey was done with 10 product development leaders and 15 product managers from the corporation developing the mobile terminals. The purpose of the survey was to verify the validity and practicality of our process in this domain. The survey contained questions focusing on the four questions below:

- How many times where the conflicts of the stakeholders dealt with in the requirements elicitation process?
- How many periods were needed to solve the conflicts during the entire requirements elicitation process?
- Was the proposed s-CRM helpful for resolving the conflicts in the domain?
- Were the results of the proposed s-CRM reliable?

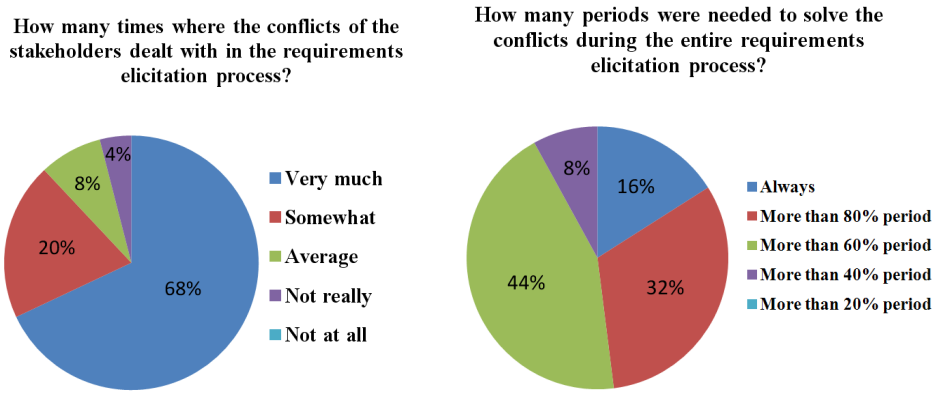


Fig. 3. The survey results for the stakeholder conflicts

For the first question regarding the stakeholders' experience with conflicts, as shown in **Fig. 3**, more than 80% of interviewees had experienced frequent conflicts as a stakeholder. For the second question related with the number of periods for solving conflicts during the entire requirements process, 16% said that conflicts are happened always. In addition, 76% confirmed that half of the periods are used up when resolving such conflicts.

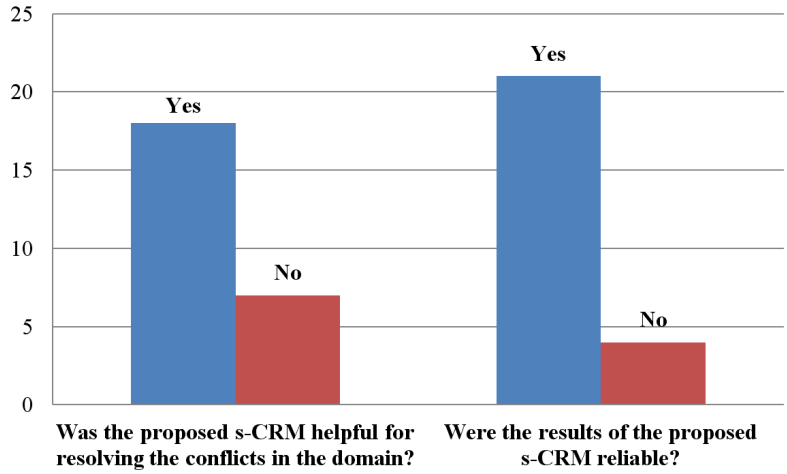


Fig. 4. The survey results for the proposed s-CRM

For the third question regarding the usefulness of the proposed s-CRM, 70% of the interviewees said that it can be helpful for resolving conflicts, while the remaining 30% gave feedback regarding the limitation in applying s-CRM model to industry owing to the complicated characteristics of stakeholders, and advised us to take into account not only the approval of the stakeholders but also the meaningful background of the rejected

requirements. For the last question about the reliability of the locked-down requirements, 85% gave positive feedback, stating that the elicited locked-down requirements are similar with their expected lists. In addition, they commented that the entropy value in each stakeholder is helpful to distinguish key stakeholders from the remaining quantitatively. It may be possible to use the entropy value as a index value to determine whether to take into account their opinions or requirements.

5. Conclusions

Although the prioritization of stakeholders has been a topic of academic interest for a long time, there are no practical models for achieving it. We mainly focused on developing an appropriate method for measuring the influence and priority and resolve the conflicts among stakeholders. In this study, the proposed stakeholder conflict resolution model (s-CRM) achieved this goal. The model consists of six phases with two steps: a) categorizing the stakeholders, b) measuring the entropy, c) prioritizing the stakeholders, d) analyzing the conflict, e) resolving the conflict, and f) locking-down the requirements. The final requirement clarifies the business goal. Briefly, the contributions of this study are as follows:

- The proposed method can measure the influence and priorities of stakeholders.
- The proposed s-CRM can solve the conflicts among stakeholders.
- The proposed method can adjust and balance the priorities of stakeholders regarding upcoming products using entropy and information gain.
- A quantitative threshold value is determined to identify the key and primary stakeholders.

Although we demonstrated the feasibility of the proposed model practically, we need to extend the suggested s-CRM for application to other domains in order to determine the proper entropy threshold values for identifying the key and primary stakeholders.

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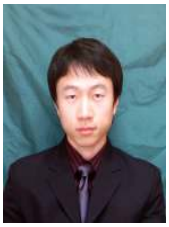
Chang-Kyun Jeon is a Ph.D. candidate in the College of Information and Communications at the Korea University and a principal engineer in the Samsung electronics. His research interests include requirements engineering, value-based software engineering, and embedded software engineering. He received his M.S. degree in Control and Instrumentation Engineering from Kwangwoon University in Seoul, South Korea.

Neung-Hoe Kim is a Ph.D. candidate in the College of Information and Communications, Korea University. His research interests include requirements engineering, value-based software engineering, software engineering economics, and embedded software engineering. He received his M.S. degree in Computer Science from Korea University.

Dong-Hyun Lee is a Ph.D. candidate in the College of Information and Communications at Korea University. His primary research interests include software engineering on embedded systems, value-based software engineering, and ubiquitous computing. He received his M.S. degree in Computer Science from Korea University.



Taek Lee is a Ph. D. candidate in the College of Information and Communications at Korea University. His research interests include software metrics, software defect prediction, information risk analysis, man-machine interaction, user behavior modeling in software system, and information security. He received his M.S. degree in Computer Science from Korea University.

Hoh Peter In is a professor of the College of Information and Communication at Korea University in Seoul, South Korea. His primary research interests are embedded software engineering, social media platform and service, and software security management. He earned the most influential paper award for 10 years in ICRE 2006. He has published over 100 research papers. He was an Assistant Professor at Texas A&M University. He received his Ph.D. in Computer Science from the University of Southern California (USC).